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3D Reconstruction of Face from 2D CT Scan Images

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Abstract

3D reconstruction of face is one of the advancements in physical modeling techniques which uses engineering methods in the field of medicine.The systems in development propose a software tool that will help in craniofacial surgery . The existing approaches for 3D reconstruction has different applications from real scenary to human parts of body. The analysis of the different algorithms allow developers to make vital decisions in understanding the modelling of the face. The human face has different regions including the tissue and hard bones. The paper presents a survey on different 3D reconstruction approaches and draws conclusions for analysing the suitable approach for a specific range of application.

Keywords : Voxel; 3D Modeling; DICOM image;Marching Cube;Ray Casting

1. Introduction

The desire to perform accurate and low risk surgery has led to the discovery of computer based surgical planning. It requires a pre-operative study as well as the simulation of surgery which predicts the output of the surgery.It helps doctors in taking right decisions even before performing the surgery. It helps to view the portion in 3D which is suspected to be infected by cancer. The craniofacial area includes the base of the skull, the facial skeleton,the underlying soft tissues and the scalp. It is a surgical subdiscipline of plastic surgery which deals with manipulation of bone.

The input of this method consists of 2 pictures at any angle. Then any 35 features are extracted from the 2 images. Then the pose estimation is done and from the feature points the 3D co-ordinates are

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computed. Then interpolation is done on it. The texture map of images are calculated. By combining the interpolation result and texture map we get the 3D model of the human face.

The 3D reconstruction generally involve constructing a 3D Model from a set of slices. The slices mean the images. The image is generally a DICOM image . By a series of steps and procedures a 3D reconstruction of the human face is generaed. The voxels are manipulated for the given set of images and the region information is extracted using projection.

The applications of 3D reconstruction vary from basic analysis for doctors to vital decision aspects. The system for 3D reconstruction is so vital that it supports for taking decisions. The systems in use support doctors for having a 3D perspective of the sliced image and also provides facility for rotation, slicing tilting, ROI extraction.

2. Literature Survey

The three dimensional techniques in medical imaging can be broadly classified into multi planar rendering(MPR), surface rendering(SR) and volume rendering(VR).

2.1Multiplanar Rendering

Multi planar reformatting (MPR) is a technique that is used to visualize the (re-sampled) grey values in arbitrary cross sections through the volumetric data. MPR is actually a two dimensional reconstruction of a CT image in a different plane. The axial slices are cut into the sagittal or coronal plane allowing to view the entire structure from the side or from front to back rather than as an axial slice cut across the structure. The relationship of the organs to each other are shown in a different view along with a view of an entire tumor in another plane may help determine treatment options. MPR studies can be obtained in any plane. The main advantage of the multi-planar reformatting method is that one is not restricted to viewing in the direction the data was scanned, which makes it possible to visualize data that was measured in different slices in one two-dimensional image. Another advantage of this visualization method is the speed. The main drawback is that the visualized data is, like the original slices, two dimensional. A single image does not give much more insight in the three dimensional structures than the measured slices.

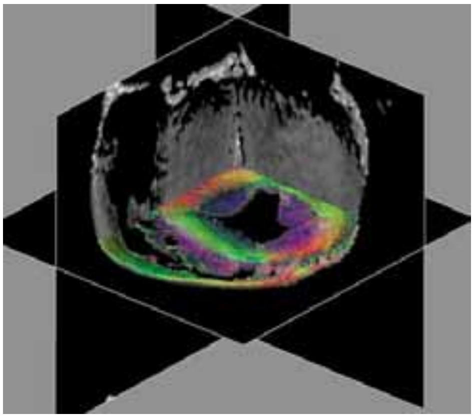

Fig. 1. Multiplanar Rendering

2.2 Surface Rendering

Surface rendering is a way to visualize the object by means of the image data as a hard set of certain basic elements, such as voxels, their faces, other polygons, line segments, and points. These sets represent either the boundary of the structure or the entire structure. An iso-surface is a three-dimensional analog of an iso-contour. It is a surface that represents points of a constant value.

Two popular method of constructing an iso-surface from a data volume like CT/MRI scan of human face are Contour based surface reconstruction and iso-surface extraction algorithms like marching cubes or marching tetrahedra.

2.2.1.Contour based surface reconstruction

A method of constructing an optimal surface over a set of cross-sectional contours is suggested by H. Fuchs, Z.M. Kedem, and S.P. Uselton[1]. Contour based reconstruction consists of Iso-contours, which are extracted from each slice can be connected to create iso-surfaces. The process consists of constructing a surface over a set of cross-sectional contours. This surface, to be composed of triangular tiles, is constructed by separately determining an optimal surface between each pair of consecutive contours. For reconstructing the three-dimensional structure, a simple manual method is sometimes employed. The images are transferred to photographic transparencies sized for table-top observation and are stacked in sequence with transparent spacers of appropriate thickness. The resulting semitransparent stack roughly approximates the original three-dimensional structure and can be examined from various angles. The contour points determined can be reduced to constructing a sequence of surfaces, one between each pair of adjacent contours.

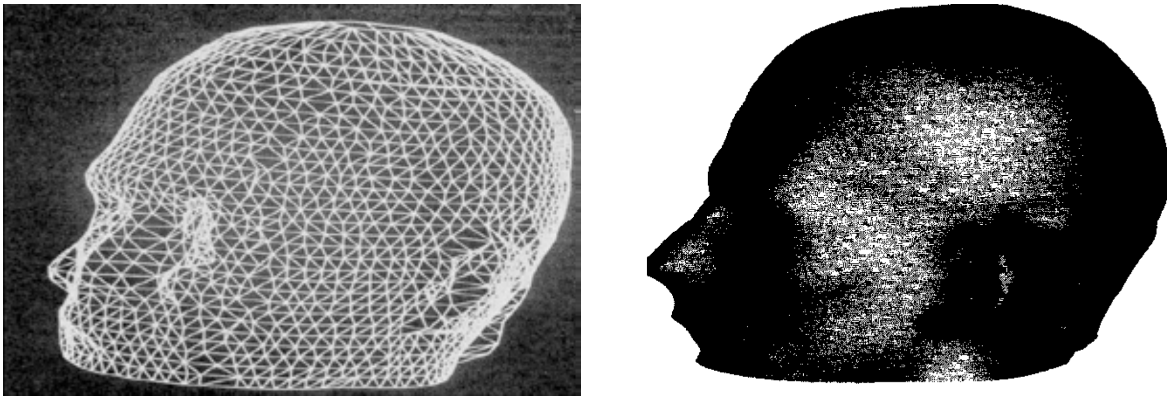

Fig. 2.(a) Optimal tiled surface defined over the contours; (b) 3D reconstruction of face

2.2.2. Isosurface Extraction based on Marching Cube

This algorithm is proposed by William E.Lorensen and Harvey E.Cline[2]. The two primary steps are locating the surface corresponding to a user specified value and create triangles.Then calculate normals to the surface at every vertices of triangles to ensure the quality of image. The algorithm determines how the surface intersects the cube, then marches to the next cube. To find the surface intersection in a cube, we assign one to a cube’s vertices if their data value exceeds or equals to the value of the surface we are reconstructing, and consider them as inside vertices. Cube vertices with values below the surface receive a zero and are consider them as outside vertices.

Therefore a logical cube is obtained to configure the surface. Since there are eight vertices in each cube, there are only 28 = 256 ways a surface can intersect the cube. Recurred to the reverse and symmetric properties of the cube, we can reduce those 256 cases to 15 patterns. Each cell face is shared by another cell. Due to such sharing, the iso-surface is continuous among adjacent cells. The algorithm provides a 3D surface reconstruction by giving physicians a 3D view of anatomy. It creates triangle models of constant density surfaces from 3D medical data. The algorithm processes the 3D medical data in scan-line order and calculates triangle vertices using linear interpolation. A 3D surface reconstruction method of medical image based on modularization has been proposed by Bin Lee, Lian-Fang Tian, Chen Ping, Hongqiang Mo and Zong-Yuan [3] .This divides the whole process of three dimensional reconstruction into different modules and parts based on functions. The different steps in the process are

a)Segmentation of the given slices to get the relevant information.

b) The output of segmentation is given as the input to the MC algorithm which produces proper isosurface which is required.

c) The whole voxels created will be searched. But to enhance the searching efficiency, the voxels that intersect with the isosurfaces are only searched.

A large amount of triangle meshes will be generated using MC algorithm. So, measures should be taken to merge some triangle meshes before applying rendering to them. Here a mesh optimization method proposed is applied. Here two vertex of a triangle mesh are merged according with the two following constraints: normal constraint and space constraint. The condition for merging two vertexes is that the two above constraints are met, and then the triangle mesh is deleted.

To overcome the above drawbacks of the MC algorithm, several approaches are adopted, such as adding a filter module and a image segmentation module, changing the single loop traversing method into small quantities parallel traversing method, adding a mesh simplifying module to reduce the number of iso-surface patches, and avoiding producing the wrong surface by use of the asymptote theory.

An improvement is suggested to basic iso-surface reconstruction by Jun Xiao, Miao Yu, Ningyu Jia [4] by adding a filter module and segmentation module in 3D reconstruction algorithm. This method proposed discusses the basic principle of MC algorithm and both the advantages and disadvantages of it. The MC algorithm is improved, and a filter module, an image segmentation module and a mesh simplifying module are added. Marching cubes algorithm is a widely used surface rendering method. But MC algorithm also has its disadvantages, such as ambiguous surface and the huge quantities of the triangle patches generated. This method improves the MC algorithm by changing traversing method into multi-line traversing method to take advantage of multi-pipeline technology.

2.4.3. Volume Rendering

Volume rendering is done using Ray Casting method. In Ray casting, also known as backward mapping, a ray is fired from each pixel in the view plane, and information from all the voxels, in the volume data, intersecting the current ray or pixel is gathered. The basic goal of ray casting is to allow the best use of the three-dimensional data and not attempt to impose any geometric structure on it. It solves one of the most important limitations of surface extraction techniques, namely the way in which they display a projection of a thin shell in the acquisition space. Surface extraction techniques fail to take into account that, particularly in medical imaging, data may originate from fluid and other materials which may be partially transparent and should be modeled as such.

The modeling basically proposes both the interior of a material and the boundary between materials to be colored[6] .Volumetric rendering includes the process of making a two-dimensional projection of a three-dimensional data set. Each element of the data set is called a voxel. The goal of volume rendering is to create a 2D image from sampled 3D values. The goal is to transform a set of samples in three dimensions to a meaningful 2D image where features of interest can be easily seen. In contrast to surface rendering, volume rendering does not use a hard set of basic elements to visualize the image, but defines a model implicitly by considering the entire image region to be a semi transparent volume and by giving opacity values to each voxels in the image region. The voxels are not displayed directly in the process of rendering, instead values from voxels are used by the transfer function to colorize the data set . Transfer function maps each value in the volumetric data set into color and transparency displayed on the screen.

Algorithms on the basis of ray casting were proposed in 1987 by Marc Levoy[7] which implement the general ray casting technique described above involve a simplification of the integral which computes the intensity of the light arriving at the eye. The method by which this is done is called "additive re-projection." It essentially projects voxels along a certain viewing direction. Intensities of voxels along parallel viewing rays are projected to provide intensity in the viewing plane. Voxels of a specified depth can be assigned a maximum opacity, so that the depth that the volume is visualized to can be controlled.

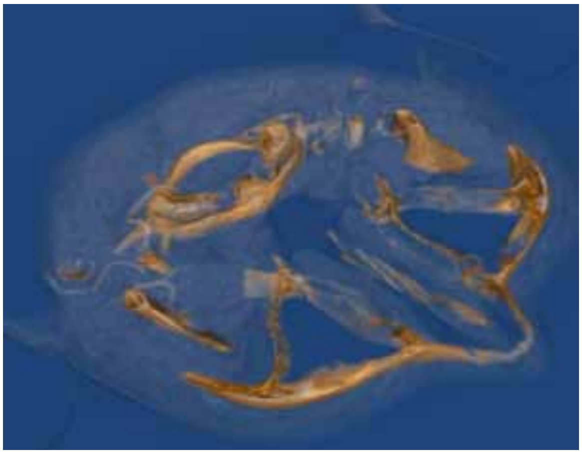

Fig. 3. A CT dataset visualized by volume rendering

The several useful features:

- The volume can be visualized from any direction.
- The transparency/opacity based transfer function will allow to see hidden and different layers.
- Coloring and shading can be used to enhance interpretation of 3D models.

An improved ray casting algorithm for medical volume visualization is presented by Vun Tian, Ming-Quan Zhou and Zhong-ke wu [8]. The algorithm first separates foreground voxels and background voxels of the volume, and mainly deals with foreground voxels, which reduces data to be disposed. The presented algorithm resamples volume data firstly, and then classifies the resampling points, which can avoid blur of the ray-casting algorithm.In addition, opacity of resample is assigned by a method with multi-freedom degree and multi-factor. This assignation method is fully related with the distance between the object and the viewpoint, as well as the distance between the object and the light source, which results in the rendered objects with high transparency definition and strong true feeling, and the weighted coefficients are expediently adjustable. The algorithm can reasonably reducing the size of volume data to be rendered, so that the technique proposed can realize real-time rendering with high quality for most medical volume data on visualization.

3. Study Results

1. In [1] the authors have proved that between each pair of adjacent contours, surfaces can be constructed . These surfaces can be associated with certain cycles which helps in finding paths. Finding such paths reduces the search space.

2. In [2] with the help of 93 CT axial slices that are 1.5mm thick and pixel dimensions of 0.8mm,MRimages of 128 coronal slices of 1.9mm and SPECT study consisting of 29 coronal slices of heart,the authors have proved that more realism can be obtained.

3. In [4] with the help of 256×256×124(12 bit) CT images, the authors have proved that the Improved Marching Cube algorithm reduces the quantity of triangular patches generated and it took less time to finish the reconstruction.

4. In [8] with the help of DICOM CT data sets of head and trunk which are of size 512×512×374×2 with 0.625000 slice thickness and 512×512×185×2 with 1.250000 slice thickness respectively from GE Medical System of Fourth Military Medical University, the authors have proved that rendered objects have high transparency definitions and strong true feeling. Also from the time cost comparison of different algorithms it is proved that Ray Casting algorithm took the minimum of those.

Table 1: Comparative analysis of different 3D reconstruction technique

Method Name	Merits	Demerits	Performance
Multiplanar Rendering[3]	1.It is possible to visualize data that was measured in different slices in a single 2D image. 2.Speed of the method	Visualization is in 2D only	Performance increases when the number of iteration increases.
Contour based surface Rendering[1]	Algorithm is efficient and it reduces the search space	Ambiguities in connecting the contour	Computation cost decreases
Marching Cube Algorithm[2]	Simple to follow the steps	Generation of ambiguous surface and huge quantities of triangular patches.	Computation is fast and results have good resolution
Improved Marching Cube Algorithm[4]	1.Reduces the triangular patches. 2.Increased speed and quality.	More computations are needed	Takes less time than standard MC algorithm to finish the reconstruction without compromising the quality of results
Volume rendering by the Ray Cast alg orithm[8]	Realize real-time rendering with high quality for most medical volume data on visualization	More computations are needed	Avoid rendering delay and the quality of result is very high

4. Conclusion

In this survey several techniques are analyzed that are available for the 3D reconstruction of facial structure which is used in craniofacial surgery for aesthetic applications. This comprehensive study of different methods gives a good understanding about the available techniques for 3D reconstruction of facial structure. From this survey it is clearly understood that Improved Marching Cube algorithm shows high performance than all other techniques and yields better results during reconstruction process.

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